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AUTHOR(S):

Chen, Pochung; Yang, Min-Fong

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Quantum Phase Transitions of Two-species Bosons

Pochung Chen¹ and Min-Fong Yang²

¹ Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan

² Department of Physics, Tunghai University, Taichung 40704, Taiwan

We calculate the ground state phase diagram of the two-component hard-core Bose-Hubbard model on a square lattice by recently proposed algorithm [1, 2] based on the tensor product states. Recently, this algorithm has been applied with success to several quantum spin systems [1, 2, 3, 4, 5] including even frustrated ones [6].

In particular, we are interested in the recently proposed paired superfluid (PSF) phase which may appear when the interspecies interaction is attractive. Other possible phases include double superfluid (2SF) phase where both species independently form superfluid and the standard Mott insulating (MI) phase. In this work we study the properties of the 2SF-PSF, MI-PSF, and MI-2SF transitions and identifies the order of transitions. We find the MI-PSF transition be second order and the value of critical point agrees well with the third-order perturbation expansion results [7]. We find the MI-2SF transition be first order when the critical point is close to the tricritical point but the transition becomes second order when the critical point moves away from the tricritical point. For the PSF-2SF transition, we find it to be second order for the parameters used in this work, but we cannot rule out the possibility of a weak first order transition when the critical point is very close to the tricritical point.

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